Automotive/Petroleum Industry Sulfur/Oxygen Test Program
Test Program Elements

- **15 Vehicles, 9 Manufacturers**
  - **3-way Catalyst Technology**
  - **Mix of Cars and Trucks**
  - **Some SFTP Intent Calibrations**

- **Goal 1**
  - **Zero sulfur effect**
  - **100, 30, <5 ppm Sulfur (Nominal 2 ppm)**
  - **"Zero" Sulfur Fuel Blended to Meet Predictive Model**

- **Goal 2**
  - **Oxygenate effect**
  - **30 ppmS sulfur base fuel**
  - **With and without 3.5 wt.% ethanol**
  - **Volatility-Matched (T_{10}, T_{50} and T_{90})**

- **Test Sequence: Start Sulfur Removal Protocol, Test 2 ppmS fuel, then in Random order test the three 30 ppmS fuels (PhII, 0% and 3.5% Oxygen), 100 ppmS fuel, Sulfur Removal Protocol, 2 ppmS fuel.**

- **Common Test Protocol at Each Site**

- **Production and Production-Intent and SFTP Prototype Vehicles Tested at Manufacturer Facilities**

- **50k or 100k Aged Catalysts**

- **Independent Statistician for Data Analysis**

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Automotive/Petroleum Industry Sulfur/Oxygen Test Program Participation

Manufacturer	**Car**	**Truck**	**Total**
1. DaimlerChrysler	1	1	2
2. Ford	2	1	3
3. GM	2	1	3
4. Toyota	TBD		2
5. Nissan	1		1
6. VW	1		1
7. Honda	1		1
8. BMW	1		1
9. Volvo	1		1
Total:	12	3	**15**

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Updated Tech 5 Sulfur/Oxygenate Proposal - Automotive/Petroleum Industry Vehicle Test Program

v. 4.1, 4/23/99

Purpose: 1) Provide additional data for CARB (short-term) and EPA (long-term) on **Fuel Sulfur** effects at near-zero sulfur levels for 1996 and later MY (Tech 5 category) vehicles. 2) Provide CARB with information on **Fuel Oxygenate** effects for these vehicles.

Objective: 1) Clarify sulfur response function below 30 ppmS fuel sulfur level. 2) Define vehicle response to fuel oxygenate levels of '0', 2.0 and 3.5% oxygen.

Participation: Worldwide automotive manufacturers, similar to previous AAMA/AIAM Sulfur Effects Project of 1997. Preliminary discussions have involved AAM (Fuels Working Group), AIAM and CRC (Emissions Committee) automotive and oil participants. Each manufacturer should endeavor to have at least one or two vehicles committed to this program. Some manufacturers have already indicated three or four vehicles will be tested. WSPA/API petroleum companies are involved as program partners and will supply the blended fuels for testing. There are currently nine automobile manufacturers indicating test participation.

Vehicles: >1995MY production or production intent three-way catalyst passenger cars and light duty trucks. Attempt to include prototype-SFTP compliant vehicles. There are presently 15 vehicles indicated for testing, including several LD trucks.

Fuels: Sulfur Effects: Near-zero sulfur level of <5 ppmS (nominal 2 ppmS). Western States Petroleum Association (WSPA) will provide a very-low sulfur base fuel (nominal 2 ppmS) , and this base fuel would be doped with di-t-butyl disulfide to obtain sulfur levels of 30 ppmS and 100 ppmS. Oxygenate Effects: California Phase 2 certification fuel (30 ppmS typical, 11% MTBE, 2.0% oxygen content) will be used. WSPA will supply two additional fuels: a volatility-matched oxygenate-free fuel (30 ppmS, 0.0% oxygen) and a volatility-matched 10% ethanol fuel (30 ppmS, 3.5% oxygen). Optional Fuel: The Federal certification fuel (Indolene, typical 30 ppmS, 0% oxygen), which would be supplied by the OEM along with a full fuel analysis to be included as part of the data.

Time-Frame: To be useful, data needs to be on the table in the July-August time-frame.

Caveat: Sulfur is present in lubricating oils, as similar compounds present in fuel,

AND as anti-wear additives, such as zinc dithiophosphate. Lubricating oil sulfur present in exhaust prevents the emissions control system from ever seeing true 'zero' sulfur, even with sulfur-free fuel. Normal lubricating oil sulfur contribution is believed to correspond to 'a few' ppmS in fuel. Vehicles will be tested with a commercially lubricating oil. Lubricating oil analyses will be included in data set.

Catalyst Aging: Although aged catalyst hardware is definitely preferable, it is not required for participation. Catalysts with 50K mile or 100K mile aging levels are to be considered. Engine- or oven-aged catalysts are acceptable. Catalyst aging plans need to be supplied at the start of the test program.

Catalyst Loading: Earlier AAMA/AIAM test program used a 30-minute idle to load catalysts with sulfur. Recent studies on later technology catalysts have indicated that that can lead to incomplete catalyst loading. The new loading procedure will be 10 back-to-back LA4 driving cycles (75 vehicle miles), to be performed after going to a new sulfur level fuel.

Sulfur Removal: The 10-WOT cycle from previous programs will be used, with ten wide-open throttle accelerations from 30 to 70 mph to drive exhaust hot and rich for total of at least 60 seconds (temperature > 700C, Lambda < 0.9, simultaneous). Added dynamometer horsepower and vehicle weight, or engine calibration control, may be necessary to achieve the temperature target and rich operation. Sulfur removal would be performed when it is necessary to get a vehicle back to it's true baseline emissions level, i.e., before and after the sulfur test series.

Per-Vehicle Test Program Outline

# of Vehicles: Each manufacturer will decide how many vehicles will be tested. All vehicles should be tested according to the following procedure.

Highest priority: **Phase 1:** Fuel Sulfur & Oxygenate Effects. 1 vehicle x 5 tests x 5 fuels (@ `0', 30, 100 ppmS) = 25 emissions tests per vehicle. The test sequence starts with `0' ppmS, then the three 30 ppmS fuels (0.0, 2.0 and 3.5% oxygen in randomized order), finishing with 100 ppmS fuel. Primary testing is on the FTP emissions cycle. Five repeated FTP tests at each sulfur level are desired to minimize test-to-test variability. As a fall-back, use Auto/Oil criteria for triplicate testing determination **(HC, 33%; CO, 70%, NOx, 30%)**. The 10-WOT cycle is necessary with the 2 ppmS fuel before starting Phase 1. The 10 LA4 cycles are necessary to assure the catalyst is loaded. At the end of this series, the 10-WOT cycle should be run to bring the vehicle back to baseline and the 2 ppmS fuel emissions tested to assure full baseline return or evaluate any baseline offset.

Next priority: **Phase 2:** Short Term Sulfur Memory Effects. After exposure to 100 ppmS fuel in Phase 1, retest at 2 ppmS after FTP pre-conditioning until emissions performance levels out. Assuming a minimum of 3 tests are required for stabilization, 1 vehicle x 3 tests x 2 fuels = 6 tests per vehicle. This Phase is to be performed separately from Phase 1.

Lowest priority: **Phase 3:** Moderate Exposure Memory Effects. Mileage accumulation on 100 ppmS fuel. Run 3,000 (or more) miles on AMA mileage accumulation procedure. Run two tests with aging fuel after mileage accumulation complete, retest at 30 ppmS after FTP pre-conditioning until emission performance levels out. Assuming minimum of 3 tests are required, 1 vehicle x 2 tests (100ppmS) + 1 vehicle x 3 tests (2 ppmS) = 5 tests per vehicle. Pre-conditioning could use US06 cycles in replacement of FTP.

Modeling: Single fuel-parameter variation data will be available in the fuel sulfur portion of the program. The entire set of emissions data is combined into a tech-group data set, along with the fuels analyses results, similar data

from earlier test programs, and then a statistical model analysis looks for evidence of fuel parameter effects within the combined data set.

Statistical Analysis: A statistician (Dr. Richard Gunst, SMU) will be contracted by AAM to analyze the sulfur portion of the data set and the oxygenate portion, separately. In addition, the data set will be provided to CARB for use in their predictive model update.

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